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(19)

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(54) ELECTRONIC ELEMENT

(71) We, MESSERSCHMITT-BOLKOW-BLOHM GMBH, a German Company of Postfach 801109, 8 Munchen 80, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to an electronic storage element which can assume two stable conditions, which are characterised by a high internal resistance, for example of 1 MΩ and by a low internal resistance, for example 300 Ω respectively.

The invention has the object of providing a storage element which can be very small; for example its size may be of the order of magnitude of 50×50 μm with a thickness of about 0.5 μm. A further object is to provide an electronic storage element which may have a simple wiring system, is resistant to radiation and contains a storage layer which is cheap and simple to manufacture. These objects are achieved according to the invention by an electronic storage element switchable between two stable resistance conditions which includes two metal electrode layers having differing electronegativity, and a layer of amorphous SiO and SiO_2 interposed between the two metal layers, the storage element having a high internal resistance in its normal condition ("off" condition) and, when a negative voltage, exceeding a certain threshold value, is applied to the electrode of higher electronegativity, the internal resistance of the storage element assumes a low value ("on" condition), the changeover to this low value of internal resistance taking place in a short time and, after the polarity of the applied voltage has been changed, the internal resistance of the storage element is returned to its original value by passing through it a current in excess of a certain value.

The invention enables large runs of the electronic storage elements to be made simultaneously, simply and cheaply. This is because each layer may be simultaneously applied for all the storage elements in a matrix thereof in a single working step, and a large part of the wiring work can be performed automatically during the formation of the electrode layers. The statement here and in the claims that the electrodes have differing negativity means that one of the electrode metals is more electronegative than the other. In this sense, in practice the electrodes always consist of a so-called precious metal, for example Ag, and a so-called base metal, for example, Al, which is electronegative with respect to Ag.

Advantageously the storage element has, in its normal condition ("off" condition), an internal resistance of, for example, 1 MΩ and the resistance attains a very small value, for example, of 300 Ω in the "on" condition, when the negative voltage is applied to the electrode of higher electronegativity, this very low internal resistance being arrived at in a very short time, for example in less than 1 μ sec. It a possible to switch from one stable switching condition into the other with voltages and currents. None of the switching conditions requires a holding voltage or holding current. Again, this means that if the external supply voltage fails, the content of the storage element is not altered thereby.

A diode element may be provided in series with the storage element, so poled that, when the polarity of the applied voltage is in the forward or "conductive" direction of the diode, the electrode of higher electronegativity assumes a positive potential relative to the other electrode of the electronic storage element. In this way it is ensured that, when a number of similar electronic storage elements are used together in a matrix of such storage elements, then none of the storage elements

in the matrix will be seriously affected by the condition of neighbouring elements in the matrix, because the individual diodes decouple the storage elements.

A plurality of similar storage elements may be juxtaposed in a two-dimensional matrix or in a three-dimensional matrix. These measures result in a very high density of storage elements, such as is for example required for use in large computer banks. Also, it is possible to link together single items of data by appropriately switching the storage system.

In order that the invention may be clearly understood and readily carried into effect, electronic storage devices in accordance therewith will now be described by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a perspective view showing a portion of a matrix having a plurality of storage elements,

Figure 2 is a plan view of the matrix of Figure 1,

Figure 3 shows a detail, in cross-section, located at the position designated "X" in Figure 2,

Figure 4 is a symbolic representation of an assembly constituted by an electronic storage element and diode,

Figure 5 is a graph showing characteristics of a storage element, and

Figure 6 is a circuit diagram showing a data read-out device for a single electronic storage element.

Each storage element in the matrix of Figure 1 is, as shown in Figure 3, composed of an electrode 10 (for example made of aluminium), of an X-ray-amorphous (i.e. not showing a crystalline structure in X-ray irradiation) insulating layer 30 made of a mixture of SiO and SiO_2 in a predetermined ratio to one another, and of a second electrode 20, which may be made of silver. The two electrodes 10 and 20 must have differing electronegativity. As shown in Figures 1 and 2, these individual elements are manufactured simultaneously and in large manufacturing runs, in matrix form and by a metallising (deposition by vapourisation) process. External connections 40, 41 enable information to be read into and out of the individual storage elements. The electronic behaviour of the individual storage elements is represented in Figure 5. In the graph of Figure 5 the characteristic curves of the storage element are plotted. Line 50, 51 represents the behaviour of the storage element in its "on" condition (low resistance), whereas line 60, 61 represents its behaviour in the "off" condition (high resistance).

In the positive section 60 ($\underline{U>O}$) of the characteristic curve, when positive voltage is applied to the electrode 10 having the higher electronegativity, then the storage element is in its high-resistance condition over a large range of voltage values. When the polarity of the applied voltage is reversed, and when it decreases (from zero value) along the section 61 of the characteristic curve, then a threshold voltage value U_s is reached, whereupon a switching action S_{EU} abruptly takes place, the behaviour of the storage element then following the pattern represented in the line 50. The behaviour of the storage element between the lines 61 and 50 is determined by the particular manner in which it is connected up to, and controlled by, the outside circuit. The storage element is now in a low-resistance state and remains in this state for a certain time in spite of changes in the applied voltage. This procedure is followed when it is desired to "read in" or store a "1 bit" in the storage element. Even if the external voltage supply is discontinued during this working phase, the low-resistance state of the storage element will be maintained. When the voltage is restored, the behaviour of the storage element will again automatically correspond to the line 50, 51 of the characteristic curve, that is to say the current flow through the storage element will respond to the characteristic curve. This enables the condition of the storage elements to be ascertained by means of circuit components (Figure 6) external to the storage element (read-out of data from the storage element). When a critical value of current i_s has been exceeded in the positive section of the characteristic curve, a switching action S_{R1} takes place, which results in a return, in a manner controlled by the external circuit components, to the line 60, 61 ("off" condition). The information previously stored in the storage element is thus erased. This condition, also, is stable when the external voltage source 70 no longer acts on the storage element. Thus, when the voltage 70 once again affects the storage element, the values of the line 60, 61 are once again followed by the storage element. It is now once again possible, by by exceeding the critical voltage value U_s of the negative section of the characteristic curve, to read "1 bit" into the storage element 90. This procedure may be repeated very often without thereby deleteriously affecting the mode of operation, described above, of the storage element. As the insulating layer 30 is amorphous, the storage system as a whole has a high resistance to radiation. A further advantage consists in the fact that the procedure of switching from line 50, 51 to line 60, 61 takes place very rapidly (in less than 1 μsec.). An advantage afforded by the storage element, in comparison with many known storage elements, is that the stored data are not lost through a reading-out action. This is because when a read-out is carried out from the storage element, with pulses of restricted current, there is no possibility of the storage

element switching over to its other condition. A further advantage afforded by the invention, in relation to the other prior art storage elements, is that, the current-control led switching effect S_{EI} (low-resistance to high-resistance), and the voltage-control led switching effect S_{EU} (high-resistance to low-resistance) lie on different sides of the lines separating the polarities of the graph of the characteristic curves of the storage element. The advantages of this type of characteristic curve are particularly marked when a number of storage elements 90 are used, each of which is series-connected with a diode 91, as shown in Figure 4. The diode 91 serves to decouple the individual storage elements, that is to say to provide protection against spurious signals obtained in the course of data read-out from one storage element, from falsely acting on a neighbouring storage element in the storage system matrix. The diode 91 and the storage element 90 are so arranged to co-operate with one another that, when the polarity of the applied voltage 70 is in the forward or "conducting" direction of the diode 91, then the pattern of signals impressed on the storage element 90 follows the positive section 51 of the characteristic curve, so that the switching effect S_{RI} can take place. When the polarity of the voltage 70 is such as to block the diode 91, then the sequence of signal values impressed on the storage element 90 corresponds to those plotted in the negative sections of the characteristic curves. When the storage element is in this state, the line 61 of the characteristic curve can be reached, with the result that the switching effect S_{RU} can take place.

By virtue of the very simple mode of construction, described above, of the storage element, and also by reason of the relative simplicity of manufacture of these storage elements (only a few working stages being necessary) it is possible to juxtapose a number of mutually-superposed tiers of these storage elements, using the same method. In this way a three-dimensional storage assembly of very great density, for example of the order of magnitude of 10^8 bit/cm^3 can be realised in practice.

As is shown in Figure 6, the voltage U of a voltage source 70 produces, through the series resistance 80, a read-out current in the storage element 90. If the storage element 90 is in its low-resistance state, then the measuring instrument 100 displays a low-voltage drop, thus providing a read-out of a specific item of data in the storage element. If the storage element 90 is in its high-resistance state, then the measuring instrument 100 displays a large voltage drop, thus providing a read-out signal of "zero" of the information contained in the storage element. By giving the voltage source 70 the appropriate polarity, and also by suitably setting the voltage U, the switching condition of the storage element 90 can be altered according to particular requirements and in the manner described above.

WHAT WE CLAIM IS:—

1. An electronic storage element switchable between two stable resistance conditions, including two metal electrode layers having differing electronegativity, and a layer of amorphous SiO and SiO_2 interposed between the two metal layers, the storage element having a high internal resistance in its normal condition ("off" condition) and, when a negative voltage, exceeding a certain threshold value, is applied to the electrode of higher electronegativity, the internal resistance of the storage element assumes a low value ("on" condition), the changeover to this low value of internal resistance taking place in a short time and, after the polarity of the applied voltage has been changed, the internal resistance of the storage element is returned to its original value by passing through it a current in excess of a certain value.

2. A storage element according to Claim 1, in which the two metal electrode layers are made by a metallising (deposition by vapourisation) method.

3. A storage element according to Claim 1 or Claim 2, in which the metal electrode layers are respectively of silver and aluminium.

4. A storage element according to claim 1 in which the said low value of internal resistance is about 300 Ω and the said short time is less than 1 μsec.

5. A storage element according to any one of the preceding claims, connected in series with a diode element so that, when the diode is in its forward or conducting direction, the electrode of higher electronegativity has a positive potential with respect to the other electrode of the storage element.

6. A two-dimensional matrix comprising a plurality of similar storage elements according to any one of Claims 1 to 5.

7. A three-dimensional matrix comprising a plurality of similar storage elements according to any one of claims 1 to 5.

8. A matrix according to Claim 7, and substantially as described with reference to the accompanying drawings.

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FIG. 1

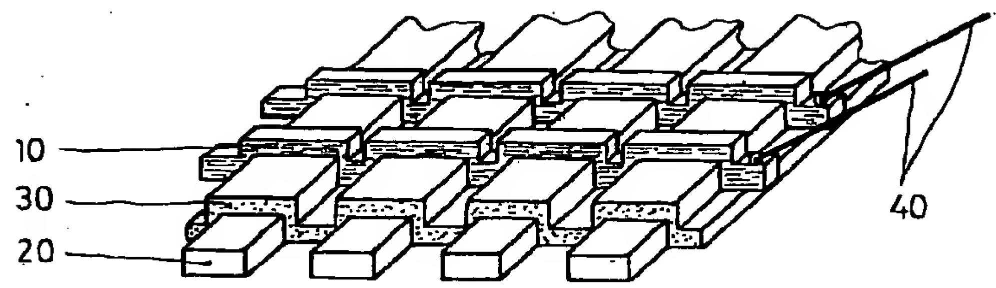

FIG. 2

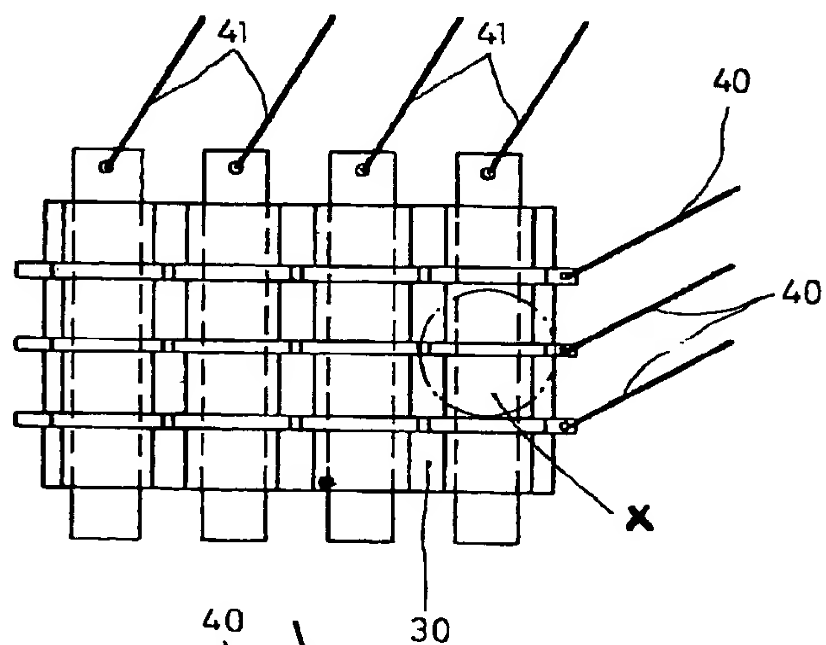

FIG. 3

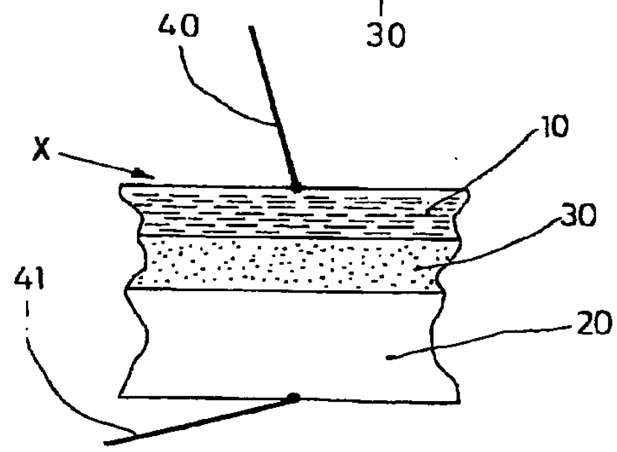

FIG. 4

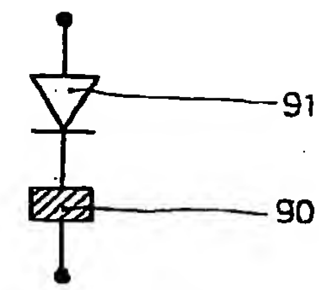

FIG. 5

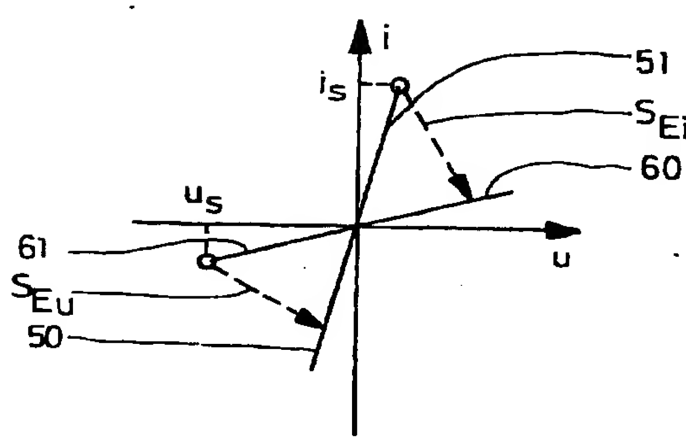

FIG. 6